DETECTING PROCESS NEUTRAL COLORS

Background of the Invention

The present invention relates to digital printing. It finds particular application in conjunction with detecting and differentiating neutrals (e.g., grays) from colors in a halftone image and will be described with particular reference thereto. It will be appreciated, however, that the invention is also amenable to other like applications.

At times, it is desirable to differentiate neutral (e.g., gray) pixels from color pixels in an image. One conventional method for detecting neutral pixels incorporates a comparator, which receives sequential digital values corresponding to respective pixels in the image. Each of the digital values is measured against a predetermined threshold value stored in the comparator. If a digital value is greater than or equal to the predetermined threshold value, the corresponding pixel is identified as a color pixel; alternatively, if a digital value is less than the predetermined threshold value, the corresponding pixel is identified as a neutral pixel.

The color pixels are typically rendered on a color printing output device (e.g., a color printer) using the cyan, magenta, yellow, and black ("CMYK") colorant set. The neutral pixels are typically rendered using merely the black K colorant. Although it is possible to render neutral pixels using a process black created using the cyan, magenta, and yellow ("CMY") colorants, the CMY colorants are typically more costly than the black K colorant. Therefore, it is beneficial to identify and print the neutral pixels using merely the black K colorant.

The conventional method for differentiating the neutral pixels from the color pixels in an image often fails when evaluating a scanned halftone image.

For example, a pixel in the halftoned image may appear as a neutral (i.e., gray) to the naked human eye when, in fact, the pixel represents one dot of a color within a group of pixels forming a process black color using the CMY colorants. Because such pixels are actually being used to represent a process black color, it is desirable to identify those pixels as neutral and render them merely using the black K colorant. However, the conventional method for detecting neutral pixels often identifies such pixels as representing a color, and, consequently, renders those pixels using the CMY colorants.

The present invention provides a new and improved method and apparatus which overcomes the above-referenced problems and others.

Summary of the Invention

A method for classifying pixels into one of a neutral category and a non-neutral category inputs a group of pixels within an image into a memory device. A color of each of the pixels is represented by a respective color identifier. An average color identifier is determined as a function of the color identifiers of the pixels in the group. One of the pixels within the group is classified into one of the neutral category and the non-neutral category as a function of the average color identifier.

In accordance with one aspect of the invention, the group of pixels are input by receiving the color identifiers into the memory device according to a raster format.

In accordance with another aspect of the invention, the pixel in the group is classified by comparing the average color identifier with a threshold color identifier function.

In accordance with another aspect of the invention, the pixels are classified by determining if the average color identifier corresponds to one of a plurality of neutral colors.

In accordance with another aspect of the invention, if the pixel within the group is classified to be in the neutral category, the pixel is rendered as one of a plurality of neutral colors; if the pixel within the group is classified to be

in the non-neutral category, the pixel is rendered as one of a plurality of non-neutral colors.

In accordance with another aspect of the invention, an output of the pixels within the group is produced.

In accordance with a more limited aspect of the invention, the output is produced by printing a color associated with the average color identifier, via a color printing device, for each of the pixels within the group.

In accordance with another aspect of the invention, the color identifiers include components of a first color space. Before the determining step, the first color space components of the color identifiers are transformed to a second color space. Furthermore, the classifying step compares the average color identifier in the second color space with a threshold color identifier in the second color space. The threshold color identifier is determined as a function of a position along a neutral axis in the second color space.

One advantage of the present invention is that it reduces the number of pixels which are detected as non-neutral colors, but that are actually used to form a process neutral color.

Another advantage of the present invention is that it reduces the use of CMY colorants.

Still further advantages of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

Brief Description of the Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating a preferred embodiment and are not to be construed as limiting the invention.

FIGURE 1 illustrates a halftoned image including a plurality of pixels;

FIGURE 2 illustrates axes showing the L*a*b* color space;

FIGURE 3 illustrates a device for detecting process neutral colors according to the present invention;

FIGURE 4 illustrates a preferred method for processing an image to detect process neutral colors according to the present invention; and

FIGURE 5 illustrates an alternate method for processing an image to detect process neutral colors according to the present invention.

Detailed Description of the Preferred Embodiments

With reference to FIGURE 1, a halftoned image **10** includes a plurality of pixels **12**. For example, in the preferred embodiment, the halftone cell **14** in the original image is captured by the scanner as a 3x3 pixel object, which includes nine (9) pixels (i.e., dots) **14**. Each of the nine (9) dots is a source of an RGB signal that an observer's eye integrates into a certain color (e.g., blue).

With reference to FIGURE 2, neutral colors in the preferred embodiment are determined within the L*a*b* color space **20**, which is generally defined by three (3) axes (i.e., the L* axis **22**, the a* axis **24**, and the b* axis **26**). The L* axis **22** represents a neutral axis that transitions from black to white; the a* axis **24** transitions from green to red; and the b* axis **26** transitions from blue to yellow. A point **28** at which the three (3) axes **22, 24, 26** intersect represents the color black. Because the L* axis **22** transitions from black to white, positions along the L* axis represent different gray-scale levels. Furthermore, close-to-neutral colors are defined as:

$$a^{*2} + b^{*2} < T_n(L^*)$$

where: $a^{*2} + b^{*2}$ represents a square of the distance from the L* axis at any point (a*, b*) along the L* axis; and

$\sqrt{T_n(L^*)}$ defines respective distances, or thresholds, from the L* axis, above which a color of lightness L* is no longer considered neutral.

In the preferred embodiment, the function $T_n(L^*)$ is represented as a cylinder **32**. Therefore, all points in the L*a*b* color space that are within the

cylinder **32** are considered neutral colors; furthermore, all points in the L*a*b* color space that are on or outside of the cylinder **32** are considered non-neutral colors. Although the function $T_n(L^*)$ is represented in the preferred embodiment as a cylinder, it is to be understood that the function $T_n(L^*)$ may take different forms in other embodiments. It is to be understood that although the preferred embodiment is described with reference to determining neutral colors in the L*a*b* colors space, other color spaces are also contemplated.

In an alternate embodiment, neutral colors in the preferred embodiment are determined within the L*C*h* color space, in which $C^{*2} = a^{*2} + b^{*2}$ (i.e., C* and h* are polar coordinates in the a*,b* plane of the L*a*b* color space). In this case, the close-to-neutral colors are defined by comparing the average color identifier in the L*C*h* space (the chroma C*) with a chroma threshold $C^*_{threshold}(L^*,h^*)$ that is determined as a function of two (2) coordinates, L* and a hue angle h*.

Regardless of what color space is used, neutral colors are defined as those colors surrounding a neutral axis.

With reference to FIGURES 1, 3, and 4, a preferred method **A** for processing an image to detect process neutral colors is shown. An image is scanned in a step **A1** using an input device **40** (e.g., a scanning input device). In this manner, each of the pixels within the image is associated with a color identifier. More specifically, the input device **40** rasterizes the image by transforming the pixels **12** into components of a first color space (e.g., the red-green-blue ("RGB") color space). Each of the components of the RGB color space serves as a color identifier of the respective pixels **12**. The rasterized RGB image data stream is stored, in a step **A2**, in a memory buffer device **42** and transformed, in a step **A3**, into a second color space (e.g., L*a*b* or L*C*h*).

The rasterized RGB image data stream is stored, in a step **A4**, into line buffer devices. By way of example, the buffers supply a stream of three (3) consecutive raster lines with pixels of interest in the second stream. The image data is averaged in a step **A5**, and a current pixel of interest ("POI") is identified in a step **A6**. More specifically, the averaging filter in the step **A5** computes, at any

moment, an average of a sub-group **14** of a specified number of the pixels **12** (e.g., a sub-group of nine (9) pixels $\mathbf{12}_{1,1}$, $\mathbf{12}_{1,2}$, $\mathbf{12}_{1,3}$, $\mathbf{12}_{2,1}$, $\mathbf{12}_{2,2}$, $\mathbf{12}_{2,3}$, $\mathbf{12}_{3,1}$, $\mathbf{12}_{3,2}$, $\mathbf{12}_{3,3}$) within the image **10**. The pixel of interest in this example is the pixel $\mathbf{12}_{2,2}$. It is to be understood that every pixel **12** within the image **10** is, in this example, included within nine averaging filters (except for pixels included in single pixel lines along the image edges).

In the preferred embodiment, the smallest averaging filter (i.e., sub-group of pixels) includes the number of pixels in the halftone cell (e.g., the nine (9) pixels $\mathbf{12}_{1,1}$, $\mathbf{12}_{1,2}$, $\mathbf{12}_{1,3}$, $\mathbf{12}_{2,1}$, $\mathbf{12}_{2,2}$, $\mathbf{12}_{2,3}$, $\mathbf{12}_{3,1}$, $\mathbf{12}_{3,2}$, $\mathbf{12}_{3,3}$ in the halftone cell **14**). Therefore, the reference numeral **14** is used to designate both the halftone cell and one of the averaging filters. It is to be understood that other sub-groups of pixels (i.e., averaging filters) including a larger number of pixels than included in the halftone screen cell are also contemplated.

In the first path (steps **A4** - **A9**), the L*a*b* image data pass to the line buffers to provide a data stream for the averaging filter, which is averaged in the step **A4**. The POI is identified in the step **A6** as $\mathbf{12}_{2,2}$, and an averaged color identifier is produced in the averaging filter **14** in the step **A5**. For example, each of the nine (9) L* components in the sub-group **14** is averaged; each of the nine (9) a* components in the sub-group **14** is averaged; and each of the nine (9) b* components in the sub-group **14** is averaged. Then, in a step **A7**, a determination is made, whether:

$$a^*_{avg}{}^2 + b^*_{avg}{}^2 < T_n(L^*_{avg})$$

where: $a^*_{avg}{}^2 + b^*_{avg}{}^2$ represents the square of the distance from the L* axis at any point (a*, b*) along the L* axis; and

$\sqrt{T_n(L^*)}$ defines respective distances from the L* axis or thresholds, above which a color of lightness L* is no longer considered neutral.

Therefore, if $a^*_{avg}{}^2 + b^*_{avg}{}^2 < T_n(L^*_{avg})$, it is determined in the step **A7** that the averaged components (L^*_{avg}, a^*_{avg}, b^*_{avg}) represent a neutral color; otherwise it is

determined in the step **A7** that the averaged components (L^*_{avg}, a^*_{avg}, b^*_{avg}) represent a non-neutral color.

If the step **A7** determines the averaged components (L^*_{avg}, a^*_{avg}, b^*_{avg}) represent a neutral color, control passes to a step **A8** and a tag indicating a neutral color is attached to the POI; in this example to the pixel $\mathbf{12_{2,2}}$. Otherwise control passes to a step **A9** for attaching a tag to the POI indicating a non-neutral color. In the preferred embodiment, a neutral color is indicated by a tag of zero (0) and a non-neutral color is indicated by a tag of one (1). Regardless of whether a neutral or non-neutral color is identified, control then passes to a step **A10** in the second path of the process (which includes steps **A11** - **A16**).

The L*a*b* image is also routed to the second path. In the second path, the L*a*b* image data is processed, in a step **A11**, by a processing unit **50** and stored in the memory buffer device **42** in a step **A12**. More specifically, data streams are synchronized in the step **A11** in order that the neutral/non-neutral tag is attached to the corresponding POI in the step **A10**. The proper synchronization is achieved by the buffer memory step **A4** in the first path and a buffer image memory step **A12** in the second path. Although the preferred embodiment shows the memory buffer unit **42** included within the processing unit **50**, it is to be understood that other configurations are also contemplated.

The tag associated with the POI image data is merged, in the step **A10**, with other tags associated with the POI. For example, if the POI is determined in the step **A7** to be of a process neutral color, a tag of zero (0) is added to other tags attached to the POI in the step **A10**; on the other hand, if the POI is determined in the step **A7** to be of a non-process neutral color, a tag of one (1) is added to other tags attached to the POI in the step **A10**.

The pixel stream is transformed, in a step **A13**, into the CMYK color space, as a function of the tags associated with the individual pixels. In the preferred embodiment, if the tag associated with a pixel is zero (0) (i.e., if the pixel is identified as a process neutral color), the L*a*b* data is transformed into the CMYK color space using only true black K colorant. On the other hand, if the tag associated with a pixel is one (1) (i.e., if the pixel is identified as a non-process

neutral color), the L*a*b* data is transformed into the CMYK color space using all four (4) of the colorants CMYK.

In an alternate embodiment, if the tag associated with the pixel is zero (0) (i.e., if the pixel is identified as a neutral color), the L*a*b* data is transformed utilizing a 100% gray component replacement ("GCR") approach (i.e., adjust amounts of the process colors to completely replace one of the process colors with a black colorant). On the other hand, if the tag associated with a pixel is one (1) (i.e., if the pixel is identified as a non-neutral color), the RGB data is transformed into the CMYK color space using a variable GCR approach (i.e., adjust amounts of the process colors to partially replace the process colors with a black colorant).

Once the L*a*b* data is transformed into the CMYK color space, the image data for the pixels are stored in the image buffer **42** in a step **A14**. Then, a determination is made in a step **A15** whether all the pixels **12** in the image **10** have been processed. If all the pixels **12** have not been processed, control returns to the step **A2**; otherwise, control passes to a step **A16** for printing the image data for the processed pixels, which are stored in the image buffer, to an output device **52** (e.g., a color printing device such as a color printer or color facsimile machine).

With reference to FIGURES 1, 3, and 5, an alternate method **B** for processing an image to detect process neutral colors is shown. This alternate method utilizes autosegmentation for determining objects (rendering classes) within an image. The image **10** is scanned in a step **B1** using the input device **40**. As discussed above, the input device **40** rasterizes the image by transforming the pixels **12** into the RGB color space. The RGB image data stream is stored in the memory buffer device **42** in a step **B2** and transformed into the L*a*b* color space in a step **B3**. A microsegmentation step **B4** determines, for each pixel, the rendering mode in which the respective pixel occurred in the scanned original image (e.g., halftone or contone) and tags the pixel accordingly. For example, the step **B4** of microsegmentation determines if the pixel is included in an edge between two (2) objects or within a halftone area. For the purpose of this description, halftone is understood to be any image rendering by dots placed either

in a regular or a random pattern. The step **B4** of microsegmentation may also determine if the POI is included within halftone or contone portions of the image **10**. If the POI is included within a halftone, an estimate of the halftone frequency is also determined and stored in another tag associated with the pixel. The image data associated with the POI is tagged, in a step **B5**, to identify the results of the microsegmentation. More specifically, the POI may be tagged with a zero (0) to indicate that the POI is included within an object; alternatively, the POI may be tagged with a one (1) to indicate that the POI is included within an edge.

As in the first embodiment, the image data, which includes the microsegmentation tag, is then passed to two (2) paths **60, 62** of the method for processing the image to detect process neutral colors. It is to be understood that the tags associated with the POI in the microsegmentation step **B4** identify, for particular rendering strategies, whether neutral determination is necessary and, if the POI is part of a halftone, an estimate of the halftone frequency.

Therefore, in the first path **60**, the processor **50** examines the microsegmentation tags, in a step **B6**, to determine if the POI is included within a halftone/contone image. Then, based upon a predetermined rendering strategy, the step **B7** determines if it is necessary to identify the POI to be rendered using merely black K colorant. If it is not necessary to make a determination between neutral and non-neutral pixels, control passes to a step **B8**; otherwise, control passes to a step **B9**.

In the step **B9**, the image data associated with the current POI is stored in the image buffer **42**. The size of the averaging filter is previously selected in the step **B6** according to the detected halftone frequency. The minimum size of the averaging filter is relatively large for a low frequency halftone and relatively smaller for a high frequency halftone. In other words, the minimum size of the averaging filter is determined as a function of the halftone frequency. Therefore, chroma artifacts, which are caused by possible neutral/color misclassifications when a single averaging filter size is used, are minimized.

In a step **B11**, a determination is made whether:

$$a^*_{avg}{}^2 + b^*_{avg}{}^2 < T_n(L^*_{avg})$$

where: a^*_{avg} represents averaged a* coordinates in the averaging filter;

b^*_{avg} represents averaged b* coordinates in the averaging filter;

$a^*_{avg}{}^2 + b^*_{avg}{}^2$ represents a distance from the L* axis; and

$T_n(L^*_{avg})$ defines a square of the decision distance from the L* axis, at the point L^*_{avg}, at which a classification from neutral colors to non-neutral colors occurs.

Therefore, if $a^*_{avg}{}^2 + b^*_{avg}{}^2 < T_n(L^*_{avg})$, it is determined in the step **B11** that the average represents a neutral color; otherwise it is determined in the step **B11** that the average represents a non-neutral color. As in the first embodiment, an appropriate tag is associated with the POI in one of the steps **B12, B13**.

In the second path **62**, the image data is windowed, in a step **B14**, according to well known techniques. It suffices for the purpose of this invention to define windowing as the second step of the autosegmentation procedure. In this step, according to predetermined rules, pixels are grouped into continuous domains Then, in the step **B8**, which receives image data from both the first and second paths, the neutral/non-neutral tags are added, for each pixel, to all other tags.

The image data are transformed, in a step **B15**, to CMYK color space as a function of the respective tags. More specifically, if the tag indicates the pixels represent a neutral color, the pixels are transformed into the CMYK color space using merely black K colorant; if the tag indicates the pixels represent a non-neutral color, the pixels are transformed into the CMYK color space using each of the four (4) cyan, magenta, yellow, and black colorants. Then, in a step **B16**, the CMYK image are stored in the image buffer **42**.

A determination is made in a step **B17** whether all the pixels in the image **10** have been processed. If more pixels remain to be processed, control

returns to the step **B2**; otherwise, control passes to a step **B18** to print the pixels in the CMYK color space.

It is to be appreciated that it is also contemplated to use image microsegmentation tags for selecting the averaging filter size wherever a halftone of a specific frequency is detected. Such use of image microsegmentation tags enables the process to proceed with image averaging and neutral detection while the windowing part of the autosegmentation is taking place, thus reducing a timing mismatch and the necessary minimum size of the buffers.

It is also contemplated that neutral detection be performed on a compressed and subsequently uncompressed image. More specifically, the chroma values may be averaged over larger size blocks (e.g., 8x8 pixels). Such averaging has the same beneficial effect on neutral detection as the filtering described in the above embodiments.

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.